First-Hand Experience with Residential micro-CHP in the United States.

STATUS AND CHALLENGES

The Scope of this Presentation

- Detached Single Family Home
- Electric Power and Heating Needs
- Home Cogeneration Status Worldwide
- Opportunity and Challenges for American Home Cogeneration
- Architecture of for Home Cogeneration of Heat and Power
- Product Requirements for Home Cogeneration
- Outlook for Home Cogeneration
- Challenges of Moving beyond Cogeneration of Heat and Power

What is needed: The Basics

Annual average electric power use of single family detached home

- Northeast = 1.15 kW
- Midwest = 1.36 kW
- South = 1.86 kW
- West = 1.25 kW

10,000 to 16,000 kWh per year depending on where you live

Energy Information Agency
(2009 latest published data)

What is needed: The Basics

Average Annual Electric Power Use

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Total Annual natural gas use (mostly heating)

- Northeast = 99.5 Million BTU
- Midwest = 99.0
- South = 58.3
- West = 60.6

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- Northeast = 99.5 Million BTU
- Midwest = 99.0
- South = 58.3
- West = 60.6

Annual Average natural gas use (mostly heating)

- Northeast = 3.3 kW
- Midwest = 3.3
- South = 1.9
- West = 2.0

Energy Information Agency

Why Cogenerate

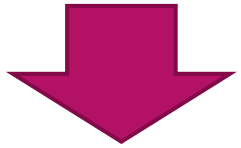
- Over 90% energy efficiency in combined generation of heat and electricity
- Generate electric power with marginal fuel use efficiency over 90% : The most efficient way to generate electricity
- Electric energy value higher than gas energy value (per unit energy), typically factor of 3.

Scoping Cogeneration Potential: Comparing Electric to Gas (heat) Energy Use

Annual Heat Demand Northern Home: 100 Million BTU

Heat Led Cogeneration of Electric Power

at 25% efficiency (electric/fuel) and 60% heating efficiency (Total 85% efficiency)



Yields 12,200 kWh of power. About the annual use for Northern home.

How Much Peak Electric Power Capacity does it take to Run a Home

Rated Watts	Description	Degrees of Power
5 kW	A basic system that can restore power to multiple "survival appliances".	Four lights, furnace fan, sump pump and refrigerator/freezer
6.5 kW	A small system to keep all the survival appliances operating and a few extras.	Survival appliances plus family room.
8 kW	A mid-Sized system to help weather powerless days and nights.	Survival appliances plus family room and home office.
10 kW	An emergency backup power system providing comfort and security.	Survival appliances plus family room, home office and kitchen.
15 kW	A system powerful enough to run a small home.	Survival appliances plus family room, home office kitchen and laundry room.
25 kW	A mini-power plant that can run a small to mid-sized home or business.	All of the above plus an air conditioning system.
30 kW and up	A mini-power plant that can run a large home	All of the above and more. Live in total comfort.

Large Experience Base: Standby Generator Market

Many homes have “200 Amp Service” = 50 kW of potential power draw from grid.

Opportunity for Electronic Load Management*

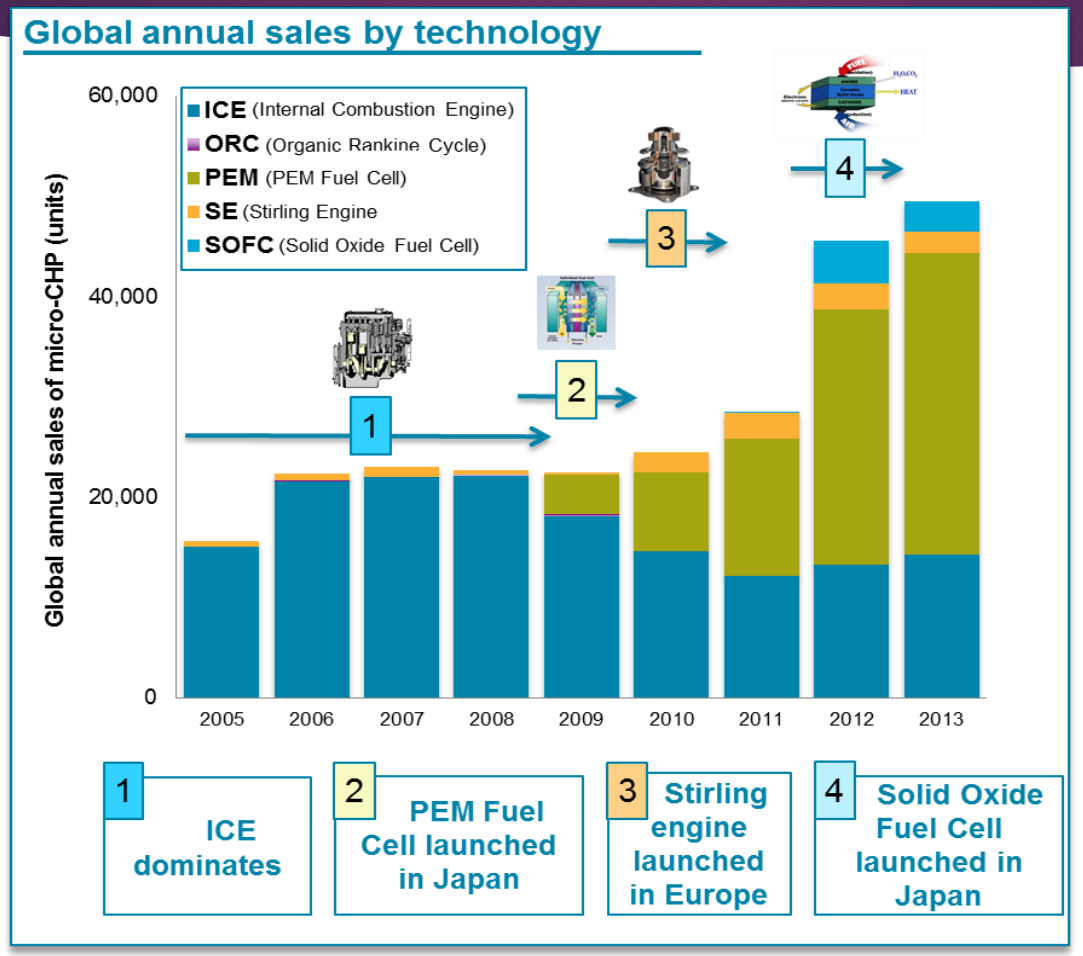
- Estimate: Peak demands can be reduced by about 50%
- Yields Rough target of about 7 kW capacity to meet loads

*** Via State-of-the-art, Programmable, Solid State Power Management System now about $1,000 for home size system**

Micro-CHP World-Wide

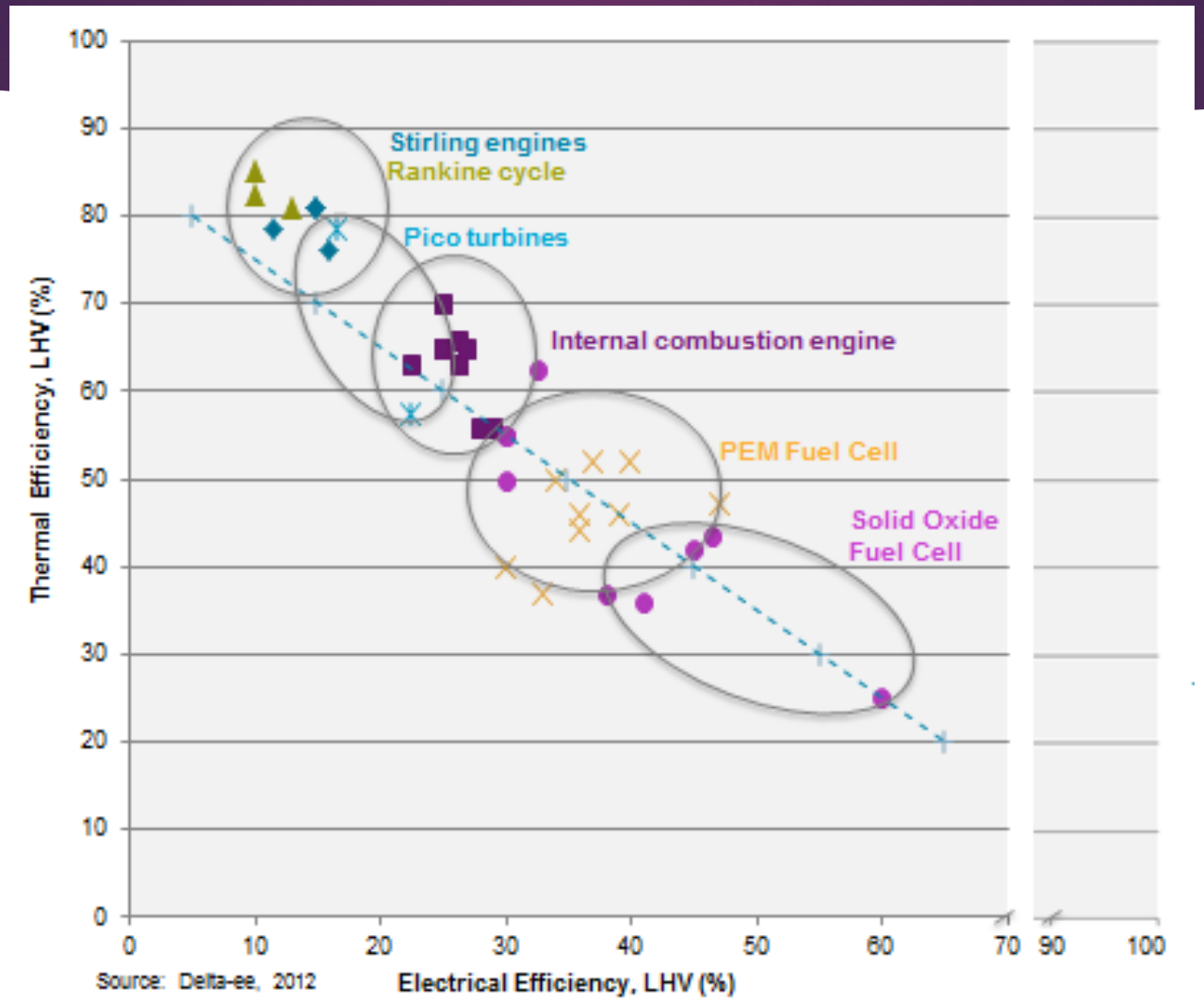
- Very small use relative to potential market size
- Mostly European and Asian resulting from government subsidies
- US situation: must compete largely unsubsidized.

Micro-CHP World-Wide



Source: Delta-ee

Status of Micro-CHP Efficiency



All fall in 80 to 95% total efficiency range

Micro-CHP Experience in American Homes

- Less that about 500 total installed units (estimate)
- Mostly Engines, a few demo fuel cells
- Most are 1.2 kW freewatt systems, balance 5 kW systems (Marathon and Yanmar) and a very few 10 kW Systems.

Internal Combustion Engines: Way Ahead of Fuel Cells on Economics for US market

- Today's Engines based Systems at fringe of acceptable economics for US.
- Today's Fuel Cell based systems are at least a factor of 10 from acceptable economics in US, in spite of achieving relatively large scale production in Asia.

Challenges of Home Cogeneration

- Thermal and Electric loads not coincident
- Electric load highly variable over day: Zero to Max, with Max at about 10 times average.
- Thermal loads highly variable over day and season.
- Residential fuel at least twice the cost of to utility company
- Need for simple interconnect to grid
- Economic benefit limited to price of electric power not drawn from grid
- Generator durability

Cogeneration System Architecture: Reconciling Electric and Heat Capacity and Energy Supply Requirements

- The fundamental driver for design of cogeneration system architecture
- Compromises needed for economically practical design
- Storage of either heat or electric is a challenge

Home Cogeneration System Architecture

- **First Generation Home Cogeneration** (**Freewatt** System by Climate Energy)

Direct replacement for Conventional Central Heating Furnace or Boiler

No storage: Electric or Thermal, Fixed Cogen Electric and Heat Output, Modulating Auxiliary heat output

Grid tied and with Net Metering

Home Cogeneration System Architecture

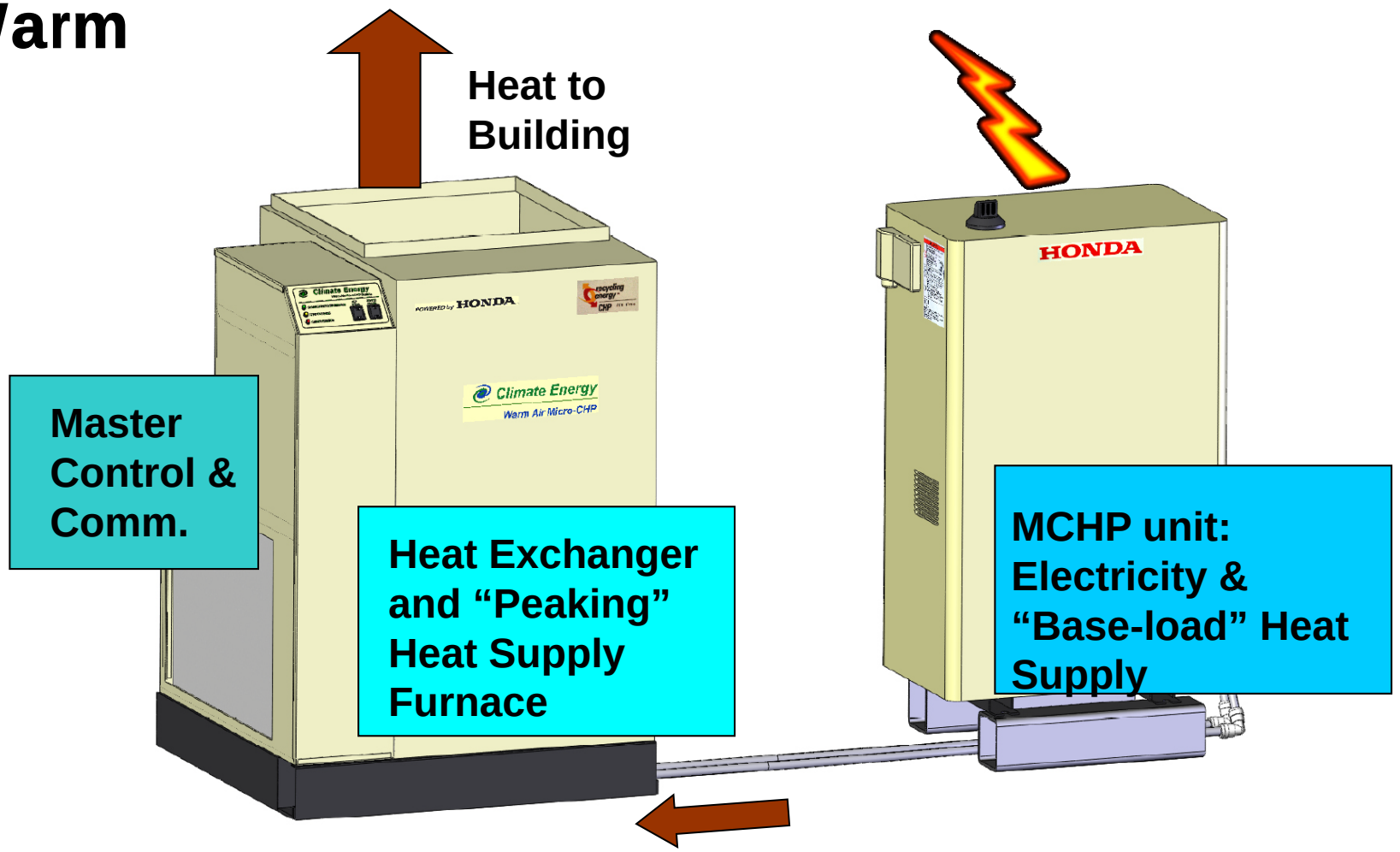
- **First Generation Home Cogeneration** (**Freewatt** System by Climate Energy)

Heat led operation with levelized heat demand (no thermostat setback), near constant cogen operation during winter

Cogeneration supplies constant low output first stage heating, conventional burner for high heating demand as needed

Target: 50 to 70% heat supplied by cogeneration while generating about 50% of annual electric demand (mostly in winter).

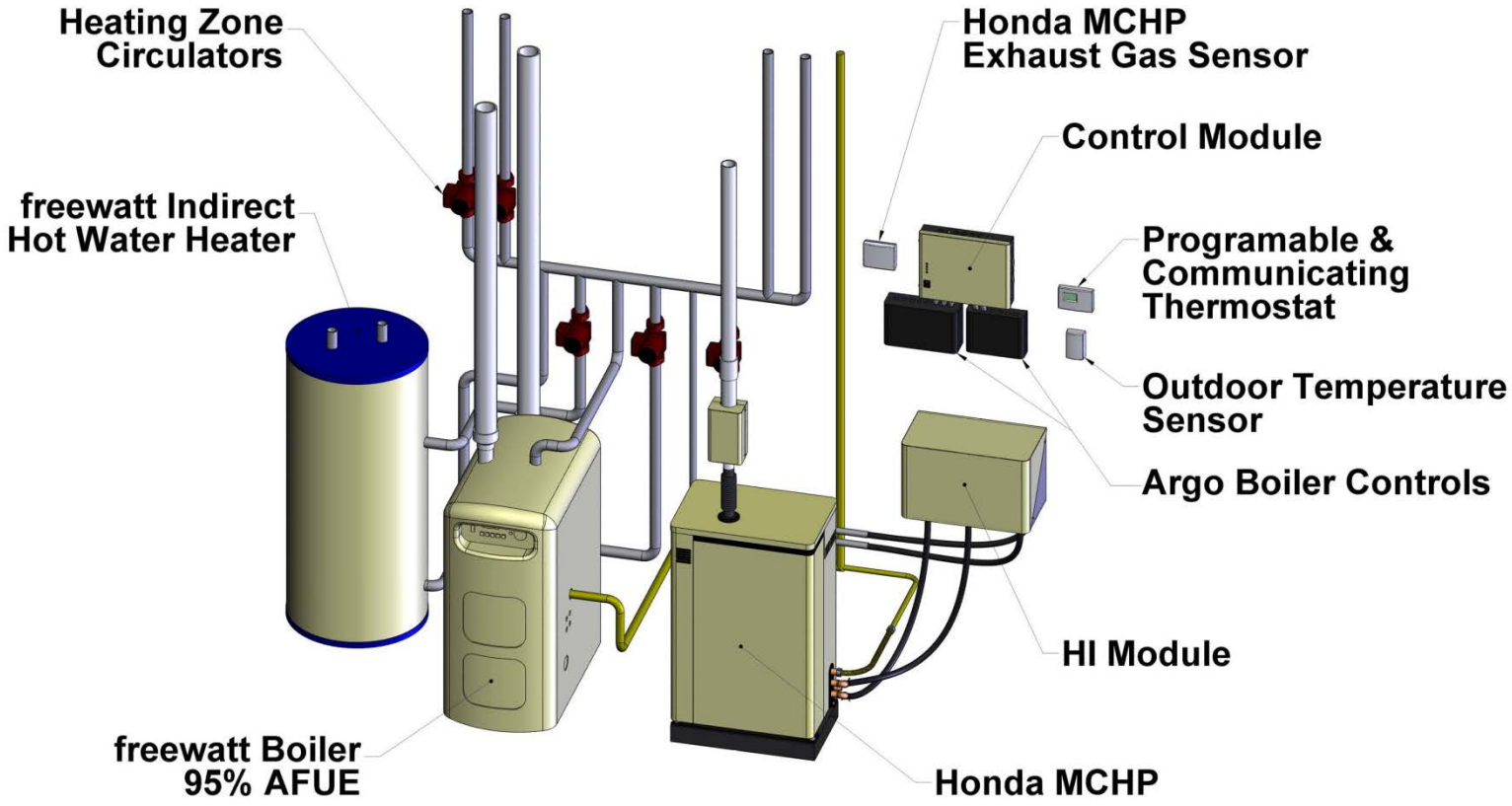
Micro-CHP System for Warm Air Heating Application



Climate Energy freewatt

Warm Air Micro-CHP Installation

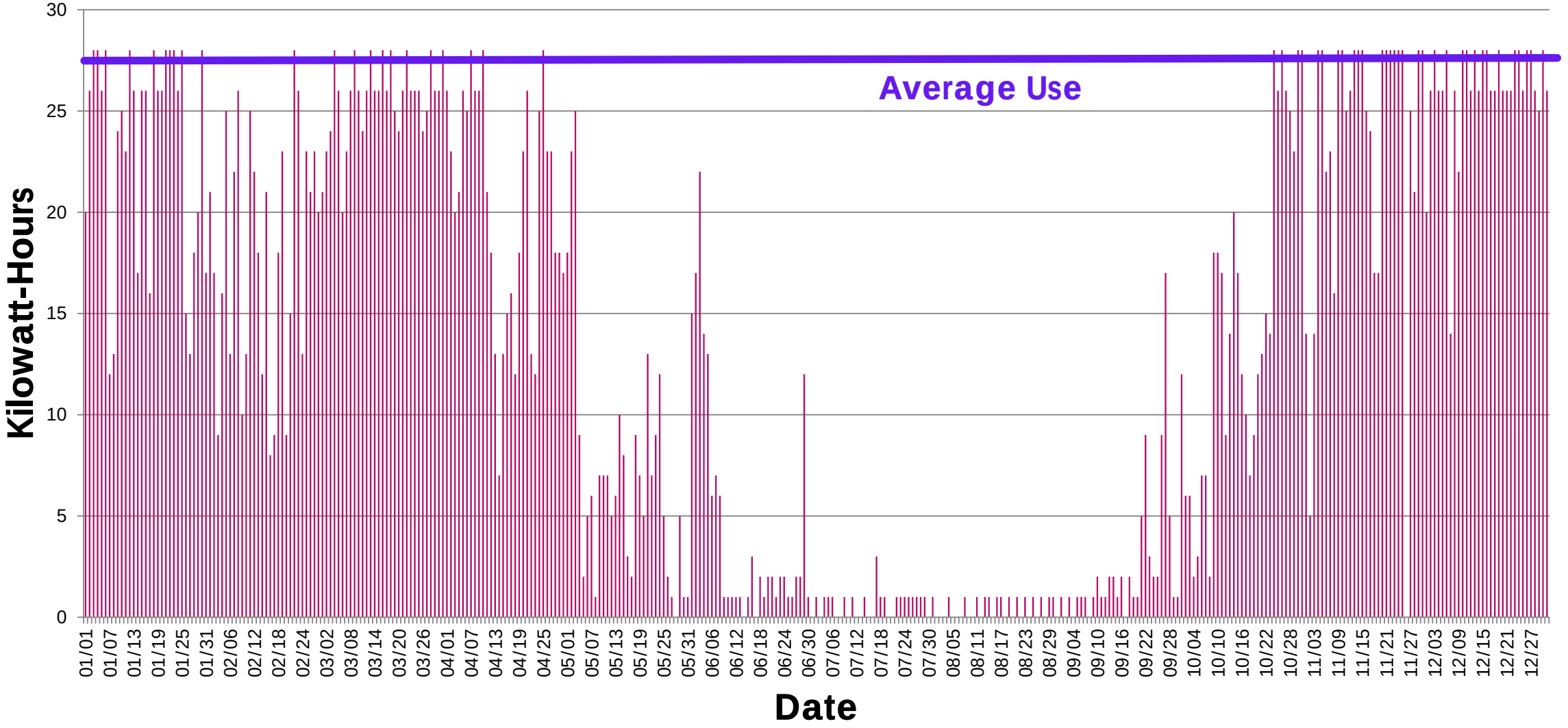
Hydronic Heating Micro-CHP




freewatt
HONDA
mCHP

For One Year Period

Typical Freewatt System Kilowatt-Hours Per Day



Home Cogeneration System Architecture

- **First Generation Home Cogeneration** (Freewatt System by Climate Energy)

No storage: Electric or Thermal

Grid tied and best applied with
(about 1 to 1.5 kW)

Heat lead with levelized heat d

Cogeneration supplies constant
high demand as needed

These Goals have been achieved in commercial practice

Target: 50 to 70% heat supplied by cogeneration while generating about 50% of annual electric demand (mostly in winter).

Home Cogeneration System Architecture

- **Vision for Second Generation Home Cogeneration System**

  heat lead, grid tied

  No thermal storage (need too much to make significant impact)

  Battery Storage supplying power high output to inverter to better match electric loads

  Higher efficiency generator to produce larger portion of annual electric (about 1 to 2 kW)

  Reasonable target: All heat and 75% electric by cogeneration.

Home Cogeneration System Architecture

- **Vision for Second Generation Home Cogeneration System**

  Heat lead

  No thermal storage (
  full impact)

  Battery Storage supp
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  Higher efficiency generator to produce larger portion of annual electric

  Reasonable target: All heat and 75% electric by cogeneration.

These Goals have yet to be demonstrated

Micro-CHP Product Requirements: Mandatory

- Inverter-based grid connection: Meets UL 1741
- UL Listed Generator: Meets UL 2200 – Stationary Engine Generators
- Very Low Noise (Lower than conventional heating systems) 45 dBa or less
- Can be installed like conventional heating appliance (indoors, similar footprint)
- Low Emissions (similar to conventional heating products) (CO and NOx < 10 PPM)
- Rapid Startup
- Total installed cost reasonable: $5,000 to $10,000 over conventional heating-only system)

Micro-CHP Product Requirements: Desirable

- Meets both space and domestic water heating requirements
- Configurations for both warm air and hydronic heating
- Can automatically supply back-up power generation during grid outage
- Can load follow during back up power generation
- Can manage electric loads during power outage
- Homeowner supervisory control through Mobile Device

Micro-CHP Net Metering: Is it needed? Will it be available?

- **Need:** Helps economics, but may not be critical with current system architecture

- **Availability:** 14 states with some allowance of micro-CHP net metering with natural gas

  Net metering under pressure

  Prediction: no further expansion and some retraction in future

Observation: Power Only generation with natural gas not likely to viewed favorably with regard to grid-tie issues: No clear environmental benefit as with CHP, utility ends up supplying full kW capacity for backup with little kWh energy sales

Home Cogeneration: Currently Impractical goals

- **Grid Independent (Reliability issue)**
- **Cogeneration of 100 % heat and 100% power requirements at Cogeneration efficiency (Can't do without massive thermal or electrical storage)**
- **Use of Heat to Produce Cooling (No affordable and practical technology at this scale)**

Bottom line on Experience with Residential Micro-CHP

Homeowners can be very happy with micro-CHP. No hassle and pays dividends

Grid Interconnection not an issue: Just meet the UL Standard

Local electrical and gas inspection authorities not roadblock for a well-designed systems

Don't expect a lot of subsidies: It is not "renewable"

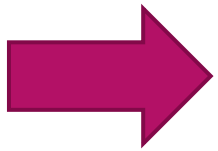
Fielding a viable product is a Mega$$$ proposition.

Achieving understanding of the concept by homeowners is big task.

Residential Micro-CHP is a technology for cold climates (about 50% of US).

Challenges of Moving Beyond Cogeneration in Homes

COGENERATION



ELECTRIC GENERATION ONLY

or

ELECTRIC GENERATION ONLY + COGEN

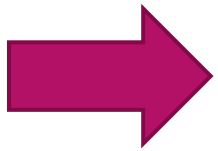
- **Cost of residential natural gas fuel compared to utility cost of fuel**

- **Efficiency of Power Conversion**

  Today, on-site, non-cogeneration (i.e. power only) with megawatt-level Commercial-Industrial Natural Gas Engine Generators operating at up to 45% efficiency has limited commercial viability (beyond backup power).

Challenges of Moving Beyond Cogeneration in Homes

COGENERATION



ELECTRIC GENERATION ONLY

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ELECTRIC GENERATION ONLY + COGEN

Power Only generation with natural gas not likely to viewed favorably by regulators and electric utilities with regard to grid-tie issues:

No clear environmental benefit as with CHP

Utility ends up supplying full kW capacity for backup with little kWh energy sales

Application R&D Needs For Second Generation Home Power Generation and Cogeneration

- **What size generator for electric energy generation?**
- **What size storage --- thermal and electric?**
- **What size inverter for electric capacity supply?**